Improvements to the NOAA WP-3D Tail Doppler Radar to Improve Resolution and Sensitivity

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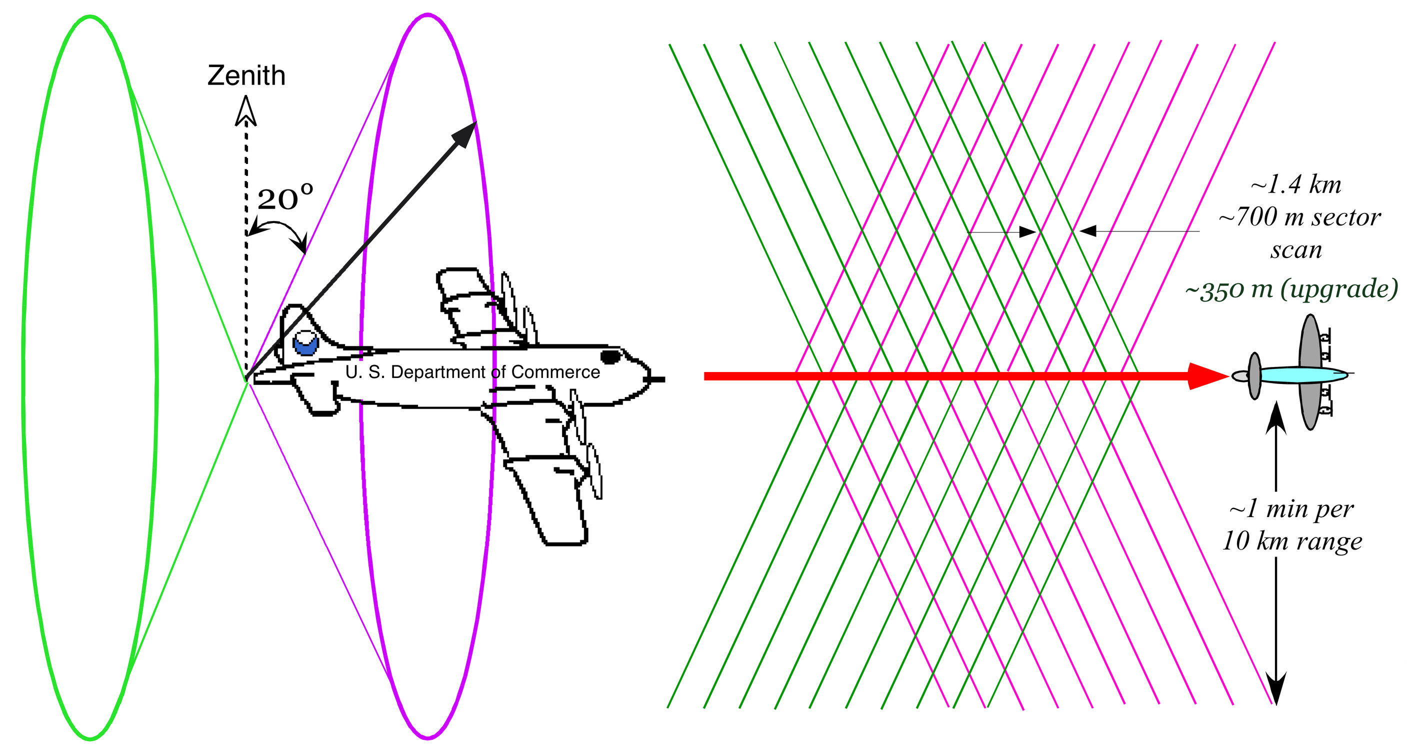
NOAA WP-3D Research/Reconnaissance Aircraft

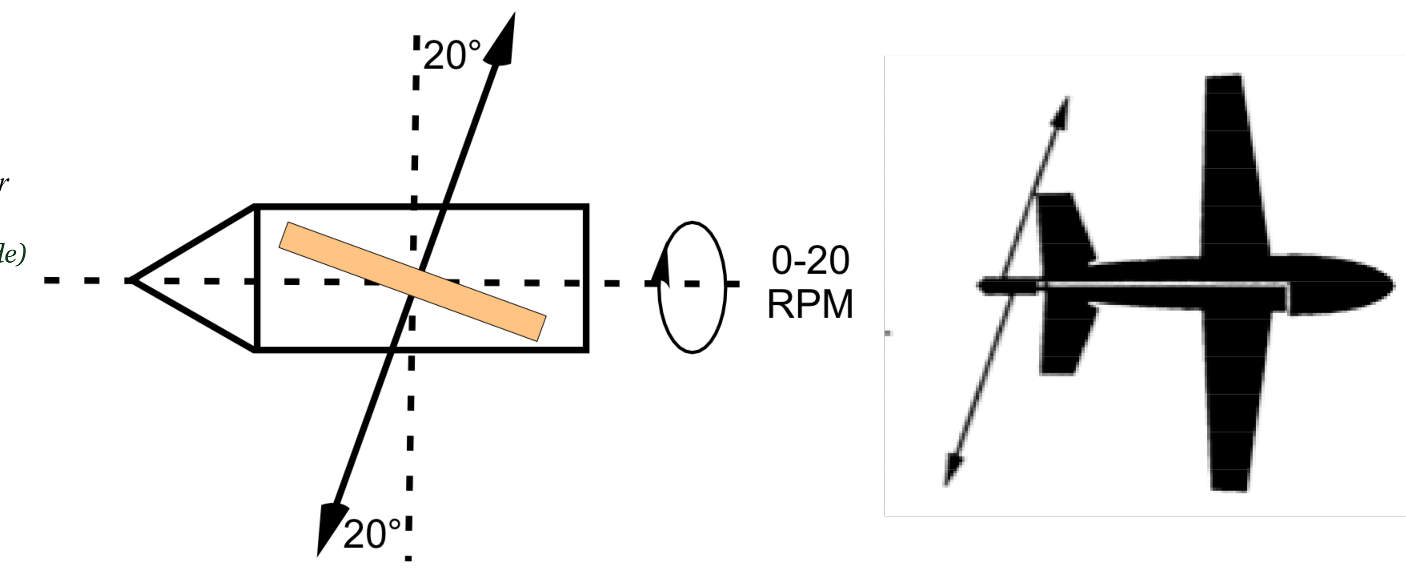
The NOAA WP-3D aircraft have been operated by NOAA's *Aircraft Operations Center* for weather and oceanic research, including hurricane reconnaissance, since the mid-1970s. The aircraft are equipped with a variety of in-situ and remote sensors including weather radars. For hurricane and tornado convective storm research the most valuable radar is the tail mounted vertically scanning X-band radar.

Tail Radar Scanning Geometry



The aircraft's airspeed is ~120 m s^{-1} and given the current tail radar rotation rate of 10 revolutions per minute (60° s^{-1}), the forward and aft looking beams intersect with a along track data spacing of ~1.4 km with a single radar that alternates transmitting fore and aft beams. The upgraded antenna will rotate about twice as fast and have a second transmitter allowing simultaneous fore and aft beams which will reduce the along track data spacing of the intersecting beams to ~350 m.

Tail Radar Antenna



The tail radar antenna consists of two flat plate antennas mounted back to back. The forward looking beam is ~20° from a plane oriented normal to the aircraft's longitudinal axis. The aft beam points ~-20° from the normal plane. The fore-aft scan technique (FAST) results in two distinct measurements at the same spatial (and nearly temporal) point. This is done to allow for a pseudo- dual-Doppler analysis to derive a 3D wind field (Jorgensen, D. P., T. Matejka, and J. D. DuGranrut, 1996: Multi-beam techniques for deriving wind fields from airborne Doppler radars. *J. Meteor. and Atmos. Physics*, **59**, 83-104.)

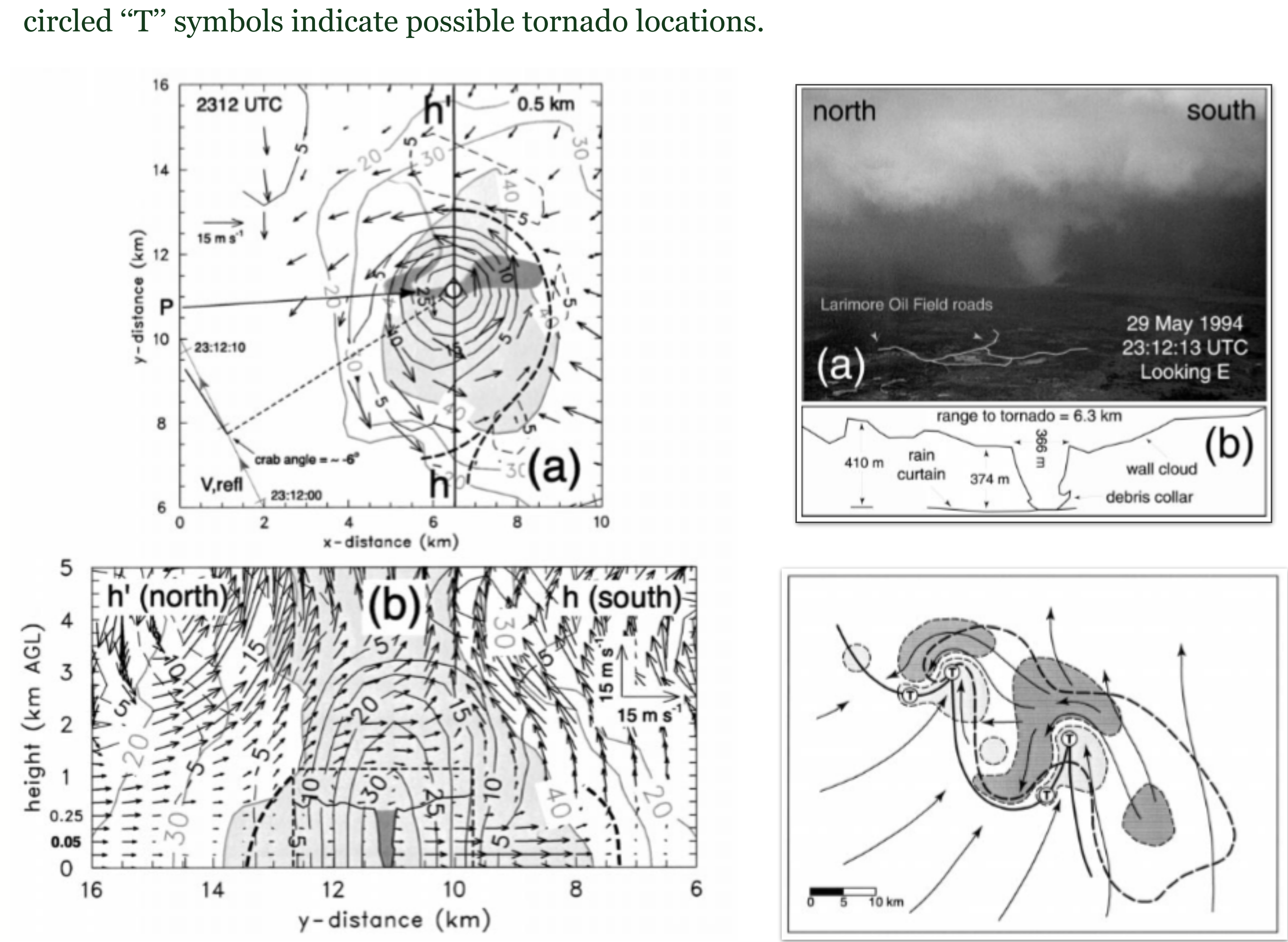
Tail Radar Upgrade Parameters

Parameter	Current Value	Upgraded Value
Wavelength	3.22 cm (X-band)	same
Pulse Repetition Frequencies	3200/2400 s^{-1}	same
Number of Pulses Integrated	47	35
Effective Vertical Smearing	1.0°	1.5°
Nyquist Velocity	±51 m s^{-1}	same
Unambiguous Range	46.9 km	same
Horizontal Beamwidth	1.90°	same
Vertical Beamwidth	1.90°	same
Antenna Rotation Rate	10 RPM (60° s^{-1})	20 RPM (120° s^{-1})
Along-Track Data Spacing	~1.4 km	~350 m
Number of Transmitter/Receivers	1	2
Minimum Detectable Signal (dBZ at 10 km)	~0	~-9
Data Processing System	Vaisala (SIGMET) RVP-8	Vaisala (SIGMET) RVP-900
Transmitter	Magnetron	Solid State
Peak Power/Average Power	65 kW/52 W	8 kW/400 W

Examples of Tornadic Storm Airborne Doppler Radar Analyses from VORTEX

NOAA P-3 Observations of the Newcastle Storm on 29 May 1994

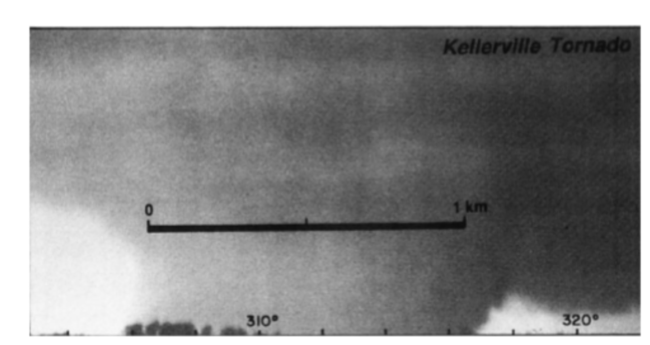
P-3 tail Doppler radar vectors, reflectivity, and vertical vorticity structure of the Newcastle mesocyclone (top left) corresponding to tornado photograph taken from the P-3 (top right). Bottom left figure shows the vertical north–south cross section, h-h'. Velocities are relative to the Newcastle mesocyclone. The dark gray filled area in (top left "a") is the Newcastle tornado damage track. The gray line at is the P-3 flight track. Bottom right hand figure is a conceptual model of the mature Newcastle–Graham storm complex in the lowest 1 km, as inferred from the Doppler analyses and derived from classical conceptual models. Heavy solid curves are mesoscale cold fronts, heavy dashed contour denotes the precipitation shield, thin black arrows are airflow stream- lines, and light and dark shading denote updraft and downdrafts areas, respectively. The circled "T" symbols indicate possible tornado locations.



Ziegler, C. L., E. N. Rasmussen, T. R. Shepherd, A. I. Watson, J. M. Straka, 2001: The evolution of low-level rotation in the 29 May 1994 Newcastle-Graham, Texas storm complex during VORTEX. *Mon. Wea. Rev.*, **129**, 1339–1368.

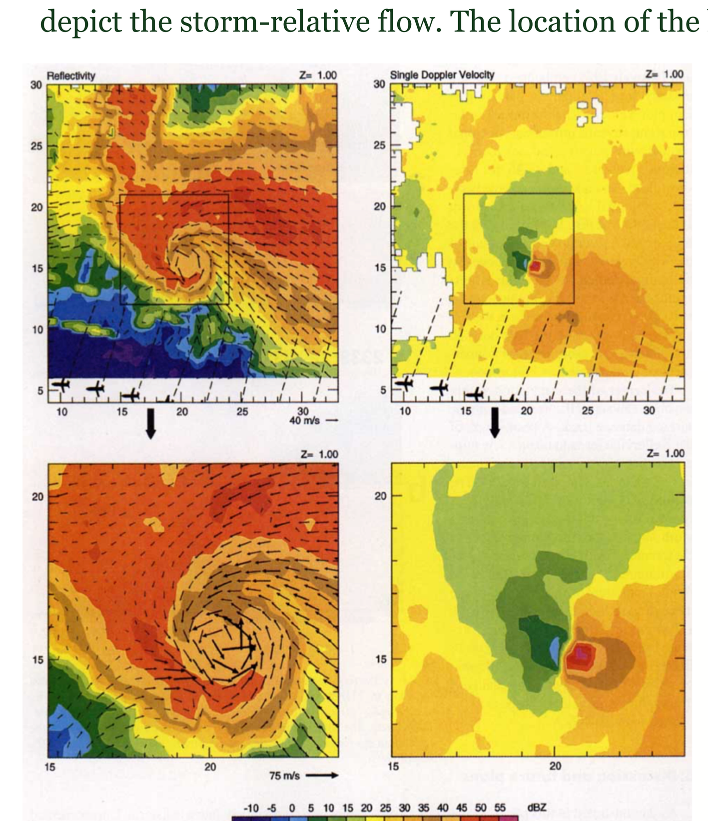
NCAR ELDORA Observations of the Kellerville Storm 8 June 1995

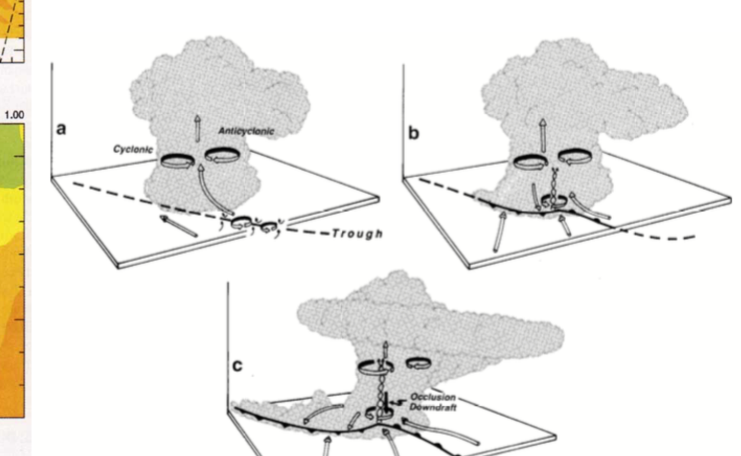
The NCAR ELDORA radar had similar characteristics to the upgraded NOAA WP-3D tail radar.



Photograph of the Kellerville tornado (left top figure). The bottom left color figures are the pseudo dual-Doppler synthesis (top left and bottom left) and single Doppler radial velocity from the aft scans (top right and bottom right figures). The black box on the top two figures is enlarged in the bottom two figures. The location of the aircraft (position shown for every eighth scan of the radar) is shown by the icon, with the dashed lines representing the viewing angle for the aft antenna. Color scale at the bottom is the values for radar reflectivity and Doppler radial velocity.

A schematic model summarizing the life cycle of the storm (bottom right figure). Cylindrical arrows depict the storm-relative flow. The location of the low-level and midlevel vorticity centers is shown by the ribbon arrows. The synoptic-scale trough is shown by the black dashed line. The rear- and forward-flank gust fronts are indicated by the frontal symbols. The occlusion downdraft is shown by the black arrow.





Wakimoto, R. M, W-C Lee, H. B. Bluestein, C-H Liu, and P. H. Hildebrand, 1996: ELDORA observations during VORTEX 95. *Bull. Amer. Meteor. Soc.*, **77**, 1465-1481.